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ZERO-Stress Amorphous Diamond

fact sheet

Researchers at Sandia National Laboratories have developed a process to create stress-free ultra-hard amorphous diamond coatings – ZERO-stress amorphous diamond – leading to a major breakthrough in the area of diamond films and tribological coatings.

The process uses an energetic carbon source to deposit, at room temperature, an amorphous carbon film with a high percentage of diamond-like bonds. Ordinarily, such films have very high levels of compressive stress, often over 7 GPa (7000 atm!). These high levels of stress make it impossible to deposit coatings thicker than about 0.2 μm and make it impossible to coat soft substrates or to create large area free-standing membranes. Sandia's patent-pending process, however, reduces the film stress to zero or even slightly tensile, permitting, for the first time, the synthesis of thick (microns) stress-free amorphous diamond coatings.

The ZERO-stress amorphous diamond films are harder than any known coating, except for crystalline diamond, with hardness and stiffness 95% of that measured for diamond. Furthermore, the Sandia process makes it possible to tailor the film stress. This permits the creation of a large area, stress-free, slightly compressive or even slightly tensile, amorphous diamond free-standing membrane. Sandia researchers have routinely grown such membranes having a diameter greater

than 1" and a thickness less than 0.06 μm . The potential to create much larger free-standing membranes still exists.

"The ZERO-stress amorphous diamond coatings represent a major advance over other types of diamond coatings," says Tom Friedmann, one of the principal Sandia scientists involved in the discovery. Unlike CVD poly-crystalline diamond coatings, which require high temperature deposition and have a rough surface morphology – often a few microns – the ZERO-stress amorphous diamond coatings are deposited at room temperature. They are atomically smooth with roughness much less than one one-thousandth of a micron. "Furthermore, these amorphous diamond films are almost identically as hard as the CVD diamond films," says Tom. These amorphous diamond films are also much



One-inch diameter ZERO-stress amorphous diamond free-standing membranes 0.1 μm thick.



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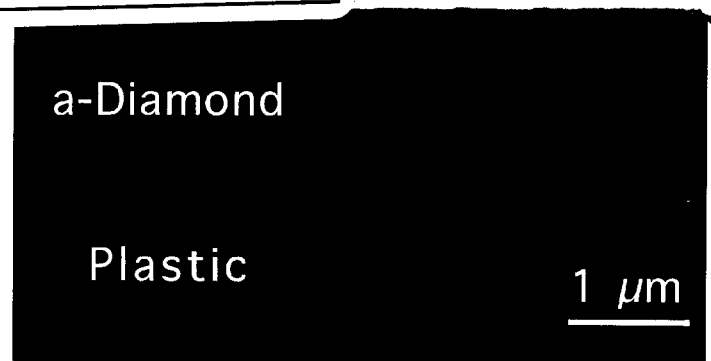
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more stable than diamond-like carbon or DLC, which is a hydrogenated form of amorphous diamond. As Tom points out, "DLC tends to degrade at temperatures as low as 200°C. The ZERO-stress films show negligible degradation up to 800°C."

The ability to create a stress-free amorphous diamond film relies on a process known as stress relaxation. "The stress relaxation that occurs in these amorphous diamond films is uniquely different from other types of stress relaxation we have seen in the past," says John Sullivan, the other principal Sandia scientist involved in the discovery. The stress relaxation that occurs in amorphous diamond involves an internal bond rearrangement process. As John describes it, "Imagine compressing a carton of volleyballs. Now imagine that some of those volleyballs can permanently transform into footballs. If enough volleyballs are transformed, then the whole carton of balls adjusts to the force being applied to it. Something similar happens when amorphous diamond stress relieves ... except it happens at an atomic level."

The Sandia scientists envision many possible uses for ZERO-stress amorphous diamond coatings. As a tribological coating, these films may be unsurpassed. They possess high hardness, high wear resistance, low coefficient of friction, are exceptionally smooth, and are inert to almost all chemicals. "ZERO-stress amorphous diamond is almost a magical material in terms of its mechanical and tribological properties," says Tom. Because the films are stress-free, deposition to almost any thickness is conceivable. Application on soft substrates becomes possible and enables the synthesis of ultra-hard coated plastics. The fabrication of a ZERO-stress amorphous diamond free-standing membrane leads to a window that is highly transmissive to optical light, x-rays, and electrons, which is important for special optical applications. "I think we have yet to scratch the surface regarding the number of possible applications for this material," says John. According to Tom, "ZERO-stress could be the breakthrough that finally enables widespread use of hard diamond-like carbon films."

Sandia has filed for a patent on ZERO-stress amorphous diamond, and companies interested in joint development or licensing can contact Craig Sheward.



1.7 μm thick ZERO-stress amorphous diamond on plastic.

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